Aug. 2, 1966 R. H. FRAZIER ET AL 3,264,144

METHOD OF PRODUCING A ROLLED STEEL PRODUCT

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Fig. 1.

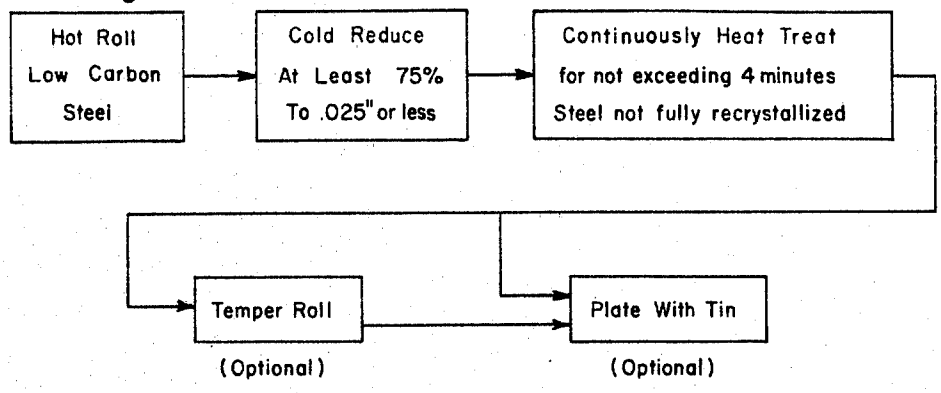
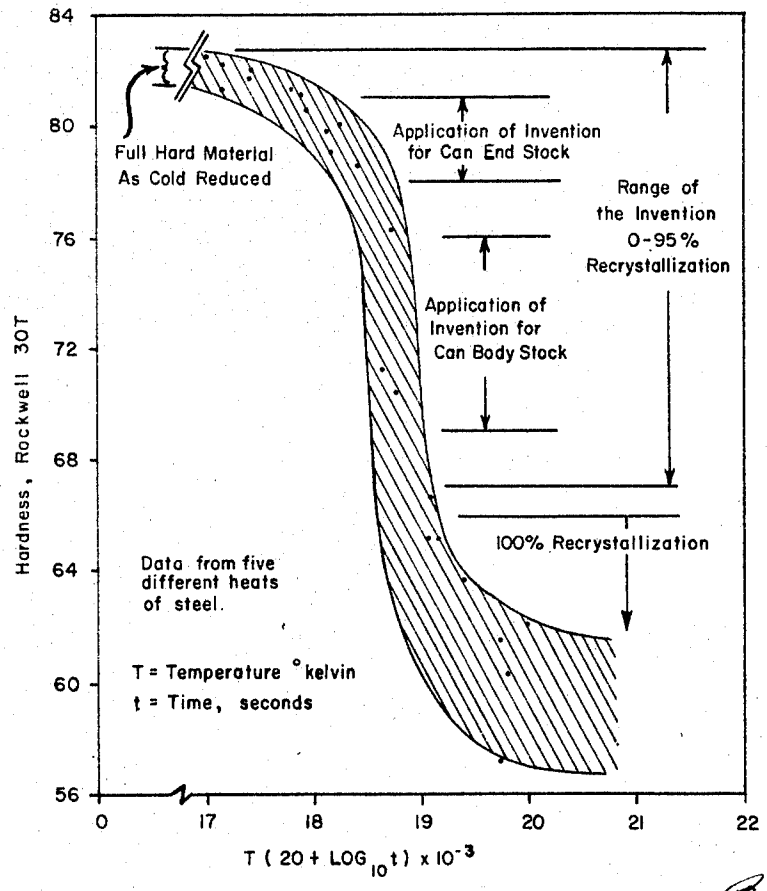


Fig. 9.



INVENTORS
Robert H. Frazier &
Robert G. Toth
Hopgood, Leonard & Bull
their Attorneys

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Fig. 3.

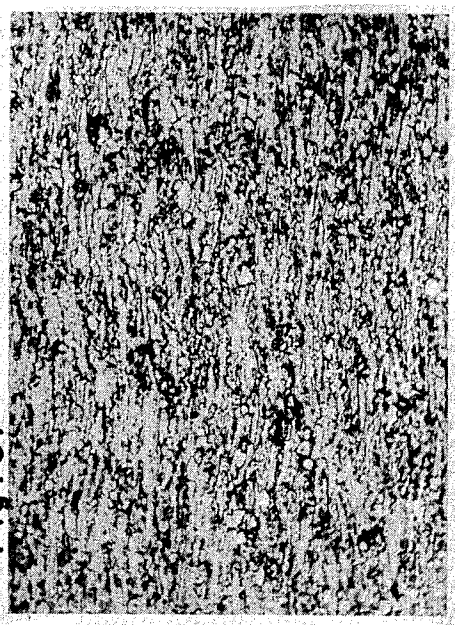


Fig. 5.



Fig. 2.

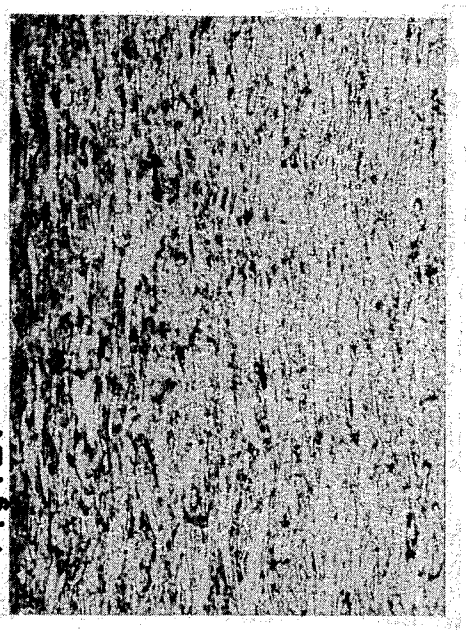
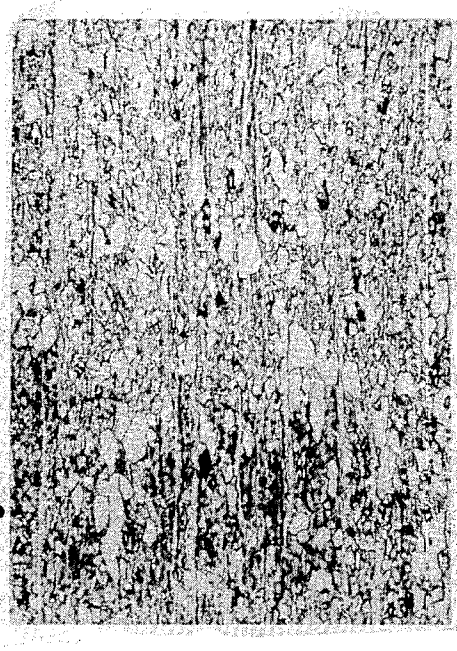


Fig. 4.



Inventors
Robert H. Frazier &
Robert G. Toth
By Hoopes, Leonard & Buell
their attorneys

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Fig. 7.

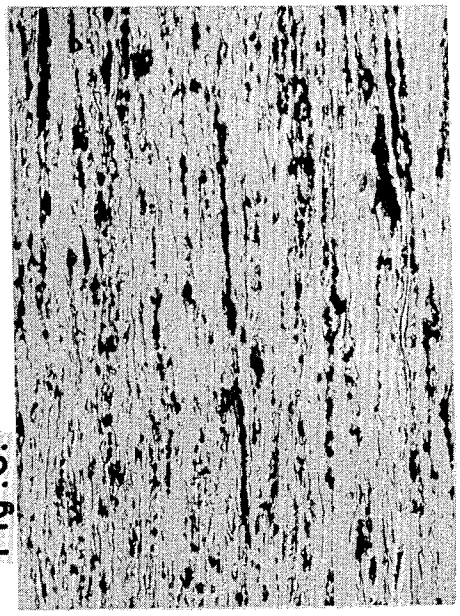


Fig. 6.



Fig. 8.

Inventors
Robert H. Frazier &
Robert G. Toth
By Hooper, Leonard & Buell
their attorneys

United States Patent Office 3,264,144 Patented August 2, 1966

3,264,144

METHOD OF PRODUCING A ROLLED STEEL PRODUCT

Robert H. Frazier and Robert G. Toth, Poland, Ohio, assignors to The Youngstown Sheet and Tube Company, Boardman, Ohio, a corporation of Ohio

Filed Aug. 21, 1963, Ser. No. 303,540
6 Claims. (Cl. 148—12)

This application is in part a continuation of our copending application Serial No. 223,400, filed September 13, 1962, now abandoned.

This invention relates to a method of producing a rolled steel product. The invention has advantages both in economy of production and quality of product and also in developing selected properties in the product. Our method produces with improved economy a rolled steel product having properties similar to the properties of rolled steel products heretofore produced only by relatively complex multistep operations at relatively great cost. Certain of the properties of our product, notably ductility, are improved. By our method the properties of the product produced may be controlled to produce optimum products for particular uses.

While our invention is not so limited in all of its aspects, it has especial application to the production of tin plate, and for purposes of explanation and illustration the invention will be described in connection with the production of tin plate.

As is well known, there is severe economic competition between packaging materials in the container field. One of the large tonnage items in that field is so-called thin tin plate. Thin tin plate has prior to our invention been typically produce in thicknesses ranging from .005" to .007" (most commonly .0066") with an ultimate strength of 65,000 to 100,000 pounds per square inch by cold reducing hot rolled strip approximately 90% to a thickness of .009", subjecting the cold reduced strip to a full anneal, further cold reducing the annealed strip by approximately 25–35% to final gauge and electrotinning; the product of such a process is known as double-reduced thin tin plate. The second cold reduction strengthens the strip while preserving some ductility in the end product. Conventional (as distinguished from double-reduced thin) tin plate is produced by cold reduction of hot rolled strip to final gauge, subjecting the cold reduced strip to a full anneal in a continuous annealing line, temper rolling the annealed strip to improve its shape and surface finish and electrotinning the strip.

The advantage of thin tin plate over conventional tin plate lies in the lower weight per unit area, coupled with high strength, of the thin tin plate. However, the double cold reduction heretofore considered necessary to develop sufficient strength in the end product for certain uses, such as can making, together with the reduction in production tonnage occasioned by the smaller weight per unit area factor, adversely affects production cost. The increased cost of producing double-reduced thin tin plate tends to destroy the competitive advantage of thin tin plate over certain other packaging materials.

We have discovered how to produce thin tin plate at greatly reduced cost without sacrificing the properties required for tin plate, especially in container manufacture. Indeed we produce at reduced cost a product superior in quality to products produced by the double reduction method heretofore employed in the production of thin tin plate. Our product exhibits superior ductility without significant loss in strength. Our product may be used otherwise than for the production of tin plate; for example, the product in unplated form may be used for making containers such as oil drums.

We hot roll low carbon steel to form hot rolled strip, continuously cold roll the hot rolled strip to reduce its thickness at least 75% to a thickness not greater than .025" and continuously heat treat the cold rolled strip at a temperature and for a time, not exceeding four minutes, such that the steel is not fully recrystallized. The product of our process may exhibit varying degrees of recrystallization or may not exhibit any recrystallization. Generally it does exhibit some recrystallization in the form of small ferrite grains in a striated matrix. Recrystallization in the product of our process may vary from 0 to 95%. The amount of recrystallization may be controlled by control of the time and temperature of heat treatment to produce rolled steel products especially adapted for particular uses.

We may temper roll the heat treated strip, depending upon the use to which the strip is being adapted. The heat treated strip, temper rolled if desired, is plated with tin when the ultimate product is to be tin plate. Tin plate thus produced has superior ductility and strength equal to or better than that of thin tin plate produced by the double reduction method heretofore employed as above described, yet due to complete elimination of the second cold reducing step heretofore deemed necessary in the production of thin tin plate our product is much less costly than thin tin plate heretofore produced. Also, as above indicated, by varying the heat treatment and hence the degree of recrystallization we can produce specific products "tailored" to particular needs, as, for example, can body stock and can end stock.

Other details, objects and advantages of the invention will become apparent as the following description of a present preferred method of practicing the same proceeds.

In the accompanying drawings we have illustrated diagrammatically a present preferred method of practicing our invention and have shown by photomicrographs examples of products produced by our invention and comparison with the prior art. In the drawings,

FIGURE 1 is a diagrammatic illustration of our invention;

FIGURE 2 is a photomicrograph of a rolled steel product produced by our invention evidencing no substantial recrystallization;

FIGURE 3 is a photomicrograph of another rolled steel product produced by our invention, the product of FIGURE 3 evidencing a small amount of, but substantial, recrystallization;

FIGURE 4 is a photomicrograph of still another rolled steel product produced by our invention, the product of FIGURE 4 evidencing a somewhat increased amount of recrystallization as compared with the product of FIGURE 3 (recrystallization of the order of 40–50%);

FIGURE 5 is a photomicrograph of yet another rolled steel product produced by our invention, the product of FIGURE 5 evidencing a further increased amount of recrystallization as compared with the product of FIGURE 4 (recrystallization of the order of 90–95%);

FIGURE 6 is a photomicrograph of a full hard (unannealed) rolled steel product of compositon similar to that of the products of FIGURES 2, 3, 4 and 5;

FIGURE 7 is a photomicrograph of a fully annealed (100% recrystallized) rolled steel product of composition similar to that of the products of FIGURES 2, 3, 4, 5 and 6;

FIGURE 8 is a photomicrograph of a rolled steel product of composition similar to that of the products of FIGURES 2, 3, 4, 5, 6 and 7 produced by cold reducing hot rolled strip approximately 90% to a thickness of .009", subjecting the cold reduced strip to a full anneal in a continuous annealing line and further cold reducing the annealed strip by approximately 25%; and

FIGURE 9 is a master hardness curve for annealing low carbon steel cold reduced 91% to 0.0066" in thickness illustrating applications of our invention. Hardness of the product varies with the degree of recrystallization and is an indication of the strength of the product.

Low carbon steel is first hot rolled to a gauge such that, when it is subsequently cold reduced at least 75%, the thickness of the cold reduced strip will be not greater than .025". The hot rolled strip is cold reduced at least 75% to a thickness of .025" or less. When tin plate is to be produced the cold reduction is preferably of the order of 90–95% and the thickness of the cold reduced strip is preferably of the order of that of thin tin plate as heretofore produced, a standard thickness being .0066". Thus we effect the entire cold reduction in a single cold reduction operation (without intermediate anneal) in contradistinction to two separate cold reduction operations with a full anneal in between as has heretofore been the practice in producing thin tin plate.

We have found that by continuously heat treating the cold reduced strip at a temperature in the range 900–1175° F. for a time, not exceeding four minutes, such that the steel is not fully recrystallized we can produce a rolled steel product which may be plated with tin to produce thin tin plate having properties like those of the previously produced double-reduced thin tin plate, and in most cases having superior properties, while saving the cost of the second cold reduction step. While the annealing temperature will generally be in the range 900–1175° F. it varies depending upon the chemical composition of the steel. The time of heat treatment is limited to four minutes or less and the steel will either not be recrystallized at all or if it is recrystallized will not be fully recrystallized but will contain small ferrite grains in a striated matrix.

A specific example of the practice of our process will now be described. A steel of the following composition may be used:

	Percent
Carbon	0.03 to 0.15.
Manganese	0.20 to 0.60.
Phosphorus	0.20 max.
Sulphur	0.40 max.
Silicon	0.010 max.
Copper	0.20 max.

The steel may be teemed into 32" x 46" bottle top ingot molds and then mechanically capped after a rimming action for not longer than 2½ minutes, 1½ to 2 minutes being preferred. The steel may be hot rolled in steps to a final gauge of 0.074". The strip so produced may be finished at an aim temperature of 1650° F. and coiled at 1150–1200° F. The strip may next be continuously pickled in sulphuric acid and may then be cold reduced 91% to a final thickness of 0.0066". The procedure may vary for the production of end products having other final thicknesses as will be understood by those skilled in the art.

The steel may next be continuously heat treated at 1075° F. for 1½ minutes. The steel is not fully recrystallized and may contain small ferrite grains in a striated matrix. The continuous heat treatment is conducted in a reducing or neutral atmosphere. We prefer to employ a dry gas consisting of 93% nitrogen and 7% hydrogen.

The microstructure of our rolled steel product is shown by the photomicrographs constituting FIGURES 2, 3, 4 and 5. All seven of the photomicrographs constituting figures of drawings herein are at 1000 diameters magnification and of specimens which are nital-etched. The microstructure of our product is in between that of full hard or unannealed steel as shown in FIGURE 6 and that of fully annealed (100% recrystallized) steel as shown in FIGURE 7. The product of FIGURE 2 produced in accordance with our invention evidences no substantial recrystallization. The product of FIGURE 3 evidences a small amount of, but substantial, recrystallization. The product of FIGURE 4 evidences an increased amount of recrystallization, of the order of 40–50%. The product of FIGURE 5 evidences further recrystallization, the recrystallization of that product being of the order of 90–95%. The small ferrite grains in a striated matrix in our product are plainly evident in FIGURES 3, 4 and 5. The fully annealed steel shown in FIGURE 7 contains randomly oriented well developed substantially equiaxed ferrite grains. FIGURE 8 shows a rolled steel product produced by cold reducing hot rolled strip approximately 90% to a thickness of .009". subjecting the cold reduced strip to a full anneal in a continuous annealing line and further cold reducing the annealed strip by approximately 25%.

The following table shows comparative properties of double-reduced thin tin plate produced by the method heretofore employed and thin tin plate produced by our method:

Material	Hardness Rockwell 30 T Mean.	Longitudinal Ultimate Tensile Strength, Mean. 1,000 p.s.i.	Olsen Cup Value Mean. Inches	Transverse Amsler Bend No. of 90° Bends to Failure Mean.
Double-Reduced Thin Tin Plate 25% Cold Reduced After Continuous Annealing (0.0066")	76	85.0	0.13	13
New Thin Tin Plate Produced by the Method Constituting the Present Invention	73	89.0	0.15	17

FIGURE 9 is a master hardness curve for annealing of low carbon steel of the type which we employ. The hardness of the full hard or 91% cold reduced steel is shown at the upper left hand corner of FIGURE 9. The hardness curve is broken at this point to indicate that this is the "as cold reduced" hardness of the full hard material without an annealing treatment. The range of our invention is shown in FIGURE 9 and also specific areas in which the invention has found specific application. Below 66 Rockwell 30T 100% recrystallization is indicated in the figure.

The time-temperature parameter $T(C+\text{LOG}_{10}t)$ is derived from a rate equation for diffusion; see Larson and Salmas, "A Time-Temperature Relation for Recrystallization and Grain Growth," Transactions of the American Society for Metals, vol. 46, p. 1377. Since it is generally believed that recrystallization and grain growth are dependent upon diffusion this time-temperature parameter is applicable to our invention. The letter C is a material constant and for steel of the type which we have used as the example, a value of 20 has been established for C.

FIGURE 9 shows a band rather than a single hardness curve. The width of the band is related to the variation in annealing response of heats of steel within the composition range above specified yet with minor variations in composition. Data from five heats were plotted to produce the hardness band shown.

Thus we produce with improved economy a product which can be used in place of previously produced products which could be produced only at much higher cost. Generally the product of our process is superior in ductility to that of thin tin plate as heretofore produced. The product of our process is competitive with materials other than steel which can be produced economically and with which the previously produced steel products have been competitive only at the sacrifice of profit to the steelmaker.

While we have described and illustrated a present preferred method of practicing the invention it is to be

distinctly understood that the invention is not limited thereto but may be otherwise variously practiced within the scope of the following claims.

We claim:

1. A method of producing a rolled steel product comprising hot rolling low carbon steel to form hot rolled strip, continuously cold rolling the hot rolled strip without intermediate anneal to reduce its thickness at least 75% to a thickness not greater than .025" and continuously heat treating the cold rolled strip at a temperature and for a time, not exceeding four minutes, such that the steel is recrystallized 0–95%.

2. A method of producing a rolled steel product comprising hot rolling low carbon steel to form hot rolled strip, continuously cold rolling the hot rolled strip without intermediate anneal to reduce its thickness at least 75% to a thickness not greater than .025" and continuously heat treating the cold rolled strip at a temperature and for a time, not exceeding four minutes, such that the steel is recrystallized 0–95% and contains small ferrite grains in a striated matrix.

3. A method of producing a rolled steel product comprising hot rolling low carbon steel to form hot rolled strip, continuously cold rolling the hot rolled strip without intermediate anneal to reduce its thickness at least 75% to a thickness not greater than .025", continuously heat treating the cold rolled strip at a temperature and for a time, not exceeding four minutes, such that the steel is recrystallized 0–95% and temper rolling the heat treated strip.

4. A method of producing a rolled steel product comprising hot rolling low carbon steel to form hot rolled strip, continuously cold rolling the hot rolled strip without intermediate anneal to reduce its thickness at least 75% to a thickness not greater than .025", continuously heat treating the cold rolled strip at a temperature and for a time, not exceeding four minutes, such that the steel is recrystallized at 0–95% and plating the heat treated strip with tin.

5. A method of producing a rolled steel product comprising hot rolling low carbon steel to form hot rolled strip, continuously cold rolling the hot rolled strip without intermediate anneal to reduce its thickness at least 75% to a thickness not greater than .025", continuously heat treating the cold rolled strip at a temperature and for a time, not exceeding four minutes, such that the steel is recrystallized 0–95%, temper rolling the heat treated strip and plating the temper rolled strip with tin.

6. A method of producing a rolled steel product comprising hot rolling low carbon steel to form hot rolled strip, continuously cold rolling the hot rolled strip without intermediate anneal to reduce its thickness at least 75% to a thickness not greater than .025", continuously heat treating the cold rolled strip at a temperature and for a time, not exceeding four minutes, such that the steel is recrystallized 0–95% and contains small ferrite grains in a striated matrix, temper rolling the heat treated strip and plating the temper rolled strip with tin.

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HYLAND BIZOT, *Primary Examiner.*

DAVID L. RECK, *Examiner.*

H. F. SAITO, *Assistant Examiner.*